



A Message From the Director of Earth Sciences

—Dr. Vincent Salomonson

By now, all of you are aware of the initiatives and changes underway at Goddard to steer the Center successfully into the next century. Among these initiatives are the reorganization of the Center, the new Strategic Implementation Plan for the Center, and the recent efforts to evaluate Goddard's quality processes in support of an application for the President's Quality Award. I appreciated how many of you attended the "all hands" meeting where I explained the implications of the Center reorganization for the Earth Sciences Directorate. For success throughout, each of these activities must take place with common goals in mind. These goals are best articulated in the Strategic Plan's six Centerwide goals to guide Goddard in fulfilling its mission and responsibilities. We in Code 900 have the seemingly formidable task of directly helping the Center to achieve these goals. Of particular note are efforts to serve as a national resource for discovery in Earth science and related technology development; to be an international Center of Excellence for research in Earth science and technology; and to

enhance the Nation's technological and scientific literacy by making the information and knowledge that result from the performance of Goddard's mission accessible to as wide an audience as possible.

Working toward achieving these goals is neither easy nor rapid. The formulation of the Strategic Plan took roughly 1 year; during that year, input from all over the Center was carefully folded into the Plan, resulting in very clear strategies for how to meet each goal. In reading through the strategies, it becomes apparent that the work done in this Directorate already meets or exceeds what was set forth in the Strategic Plan. For example, one of the strategies to achieve the goal of Goddard's development as an international Center of Excellence involves ensuring that the Center has the resources, experience, competence, and capabilities to perform world-class science, technology development, and engineering in its core areas of responsibility. Several of the articles in this issue demonstrate this point. For instance, the Center has demonstrated its ability to serve as a national

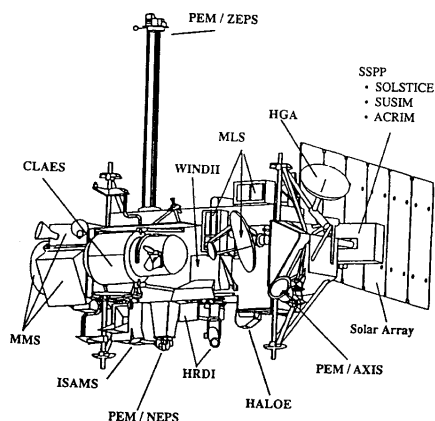
resource for discovery in Earth and space science and technology development with the significant results garnered from the Upper Atmosphere Research Satellite. In terms of excellence in Earth and Space Science, one need only point to the work that

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UARS's Amazing Journey



The Upper Atmosphere Research Satellite (UARS) has been quietly taking data that have been producing spectacular results since its launch on September 15, 1991. Considered the first of the Mission to Planet Earth series of NASA spacecraft, UARS was conceived and developed to study the middle and upper layers of Earth's atmosphere, where the protective ozone layer resides. With an original mission lifetime of 18 months, UARS has far exceeded all expectations, and is still largely functional and still sending back data. Of the original 10 instruments, 8 are still operational.

The accompanying box shows the instruments, their primary objectives, and their status.

What may, at first glance, seem like unnecessary duplication in the instruments and their measurements is actually the best way to measure atmospheric trends. UARS is an important mission to discover and study trends in Earth's stratosphere and mesosphere. The mission goals are to study how the gases in the various atmospheric layers interact over time; to study the dynamics of the stratosphere and mesosphere; to study

UARS Instrument	Measurement	Primary Objectives	Status
ACRIM—Active Cavity Radiometer Irradiance Monitor	Total solar irradiance	Observe trends in total solar irradiance	Operational
CLAES—Cryogenic Limb Array Etalon Spectrometer	Ozone, chlorine nitrate, nitric acid, nitrous oxide, methane, water, aerosols, N_2O_5 , NO, NO_2 , temperature	Observe ozone, nitrogen and chlorine reservoir species in the stratosphere	Mission completed May 5, 1993
HALOE—Halogen Occultation Experiment	Ozone, water, methane, aerosols, HCl, HF, NO, NO_2 , temperature	Observe trends in stratospheric ozone, methane, water and the products of chlorofluorocarbon photolysis	Operational
HRDI—High Resolution Doppler Imager	Mesospheric, stratospheric winds, aerosols	Observe stratospheric and mesospheric winds	Operational
ISAMS—Improved Stratospheric and Mesospheric Sounder	Ozone, aerosols, CO, methane, nitric acid, nitrous oxide, NO, NO_2 , N_2O_5 , temperature	Observe ozone, nitrogen radical and reservoir species	Failed July 1992
MLS—Microwave Limb Sounder	Ozone, water, chlorine monoxide, nitric acid, temperature	Observe ozone, water, and chlorine monoxide radical	Water vapor radiometer failed April 23, 1993 otherwise operational
PEM—Particle Environment Monitor	Energetic particle flux, x-ray backscatter, magnetic field	Observe high energy particles that would influence atmospheric chemistry	Operational
SOLSTICE—Solar Stellar Irradiance Comparison Experiment	Solar UV spectra	Provide long-term measurements of solar ultraviolet and far-ultraviolet radiation at the top of Earth's atmosphere	Operational
SUSIM—Solar Ultraviolet Spectral Irradiance Monitor	Solar UV spectra	Provide long-term measurements of solar ultraviolet and far-ultraviolet radiation at the top of Earth's atmosphere	Operational
WINDII—Wind Imaging Interferometer	Mesospheric and thermospheric winds	Observe winds in the mesosphere and thermosphere	Operational

how natural and human-induced phenomena affect the distribution of those gases; and to study the Sun and its cycles, and the effect of the Sun's radiation and particle flux on Earth.

The achievements below are among the most important contributions of the satellite to date:

Seasonal mapping of chlorine radicals and reservoirs in the lower stratosphere. A few months after launch, MLS was able to map ClO (chlorine monoxide—an ozone-destroying radical) within the Arctic vortex showing the extent of ClO formation and its close association with polar stratospheric cloud (PSC) formation. Not only was this an important confirmation of earlier aircraft results, but it also showed the extent of the zone of elevated ClO. Since these initial observations, UARS has continued to monitor both the Arctic and Antarctic late winter–spring ozone depletions. The Northern Hemisphere depletion during January–March 1996 was the largest ever.

Containment of polar vortex chemistry within the vortex region. At the time of the launch of UARS, some scientists speculated that the ozone-destroying chemicals within the polar vortex would leak to midlatitudes. Other scientists argued from a dynamical perspective that containment of the chemicals must occur. It was not until the launch of UARS and the mapping of long-lived gases, whose distributions reveal patterns of transport by the winds, that containment could be demonstrated.

Descent in the center of the polar vortex. HALOE scientists were the first to notice very low concentrations of the long-lived trace gas methane in the center of the spring Antarctic polar vortex. Analysis showed that very low values of methane exist within the mid- and upper stratosphere in late fall and that these values descend to the lower stratosphere by late spring, a net

change of 12–15 km over 6 months. This amount of descent is remarkable in any part of the atmosphere, and was later confirmed by measurements from CLAES and ISAMS.

Infrared mapping of aerosols and PSC's. Mt. Pinatubo erupted on June 15, 1991, injecting up to 20 megatons of sulfur dioxide directly into the stratosphere. Reaction of sulfur dioxide with stratospheric hydroxyl produces sulfuric acid, which condenses into aerosols at stratospheric temperatures and pressures. UARS observations by the instruments CLAES, HALOE, and ISAMS were used to track the aerosol cloud from its infrared emissions. This is the first near-simultaneous mapping of volcanic aerosol layers and their chemical perturbations.

First direct measurement of winds from space. Both WINDII and HRDI on UARS were built to measure winds from space. Although the techniques are different, both rely on the Doppler shift of an oxygen emission line in the mesosphere. HRDI additionally detects daytime stratospheric winds using the Doppler shift of an oxygen absorption line in the stratosphere. These are the first remote spaceborne wind sounders. HRDI and WINDII together have been able to give the first complete global picture of the atmospheric tide. HRDI has also been able to measure the tropical quasibiennial oscillation winds in the stratosphere.

First global maps of chlorofluorocarbons and their products from space. Some people outside the scientific community believe that chlorofluorocarbons are not responsible for ozone loss at the poles. They argue that chlorofluorocarbons are heavy molecules and will never rise into the stratosphere. High levels of observed stratospheric chlorine are due to volcanic activity, they argue. CLAES has detected large amounts of both CFC13 (F11) and CF2Cl2 (F12) in the stratosphere. As

the chlorofluorocarbons are broken down in the stratosphere, they release chlorine and fluorine, which form hydrogen fluoride (HF) and hydrogen chloride (HCl). HF is a long-lived trace gas with no important natural stratospheric sources. HALOE has detected HF and HCl in the stratosphere and found that both gases are increasing at the same rate as the CFCs are increasing in the troposphere.

Tropical transport in the stratosphere. The long lifetime of the UARS mission has led to some remarkable trace gas trend information. One of the more dramatic observations has been the vertical transport of water vapor upward in the tropical stratosphere. The amount of water vapor entering the stratosphere changes throughout the year as the tropical tropopause gets colder and warmer. These variations in water vapor ascend slowly into the stratosphere and appear coherent to about 30 km (from 16 km). The water vapor observations tell us that the tropical region must be relatively isolated from the rest of the stratosphere or these variations would be diluted.

Measurement of the UV and visible component of solar variability. ACRIM records the total solar irradiance while SOLSTICE and SUSIM measure the UV flux from Lyman alpha (~121.6 nm) up to around 400 nm. SOLSTICE uses stars, while SUSIM uses onboard calibration lamps to correct for instrument changes over time. UARS was launched near the end of the maximum of solar cycle 22, and now the Sun has reached the minimum between solar cycles 22 and 23. A comparison of energy change over this period by these instruments shows that the UV variation accounts for 40 % of the change in the total solar irradiance.

The role of energetic particles in stratospheric chemistry. Energetic particle
(Continue on page 12)

TOPEX/Poseidon Mission Lives on at Goddard Space Flight Center

In 1979, NASA and the Jet Propulsion Laboratory began planning an ocean topography experiment, TOPEX, that would use a satellite to measure the height of the world's oceans. At the same time, the French space agency, Centre National d'Études Spatiales (CNES), was designing an oceanographic mission called Poseidon, named for the Greek god of the sea. In the early 1980's these groups pooled their resources to form a single mission called TOPEX/Poseidon. TOPEX/Poseidon is a vital part of a strategic research effort to explore ocean circulation and its interaction with the atmosphere. It complements a number of international oceanographic and meteorological programs, including the World Ocean Circulation Experiment and the Tropical Ocean and Global Atmosphere Program, both of which are sponsored by the World Climate Research Program. The instruments on TOPEX/Poseidon measure the precise shape of the ocean's surface and how this surface changes through time. With this information, scientists in the Oceans and Ice Branch (Code 971) in Goddard's Laboratory for Hydrospheric Processes (Code 970) have been able to calculate ocean currents and identify climate trends in close collaboration with other organizations, such as the Scripps Institute of Oceanography and NOAA, as well as with their French colleagues.

During its first 3 years in orbit, TOPEX/Poseidon has continuously observed global ocean topography; produced the first global views of seasonal changes of currents; monitored El Niño and large-scale features such as Rossby and Kelvin waves; provided global data to validate models of ocean circulation; mapped year-to-year changes in heat stored in the upper ocean; produced the most accurate global maps of tides ever; and improved our knowledge of Earth's gravity field.

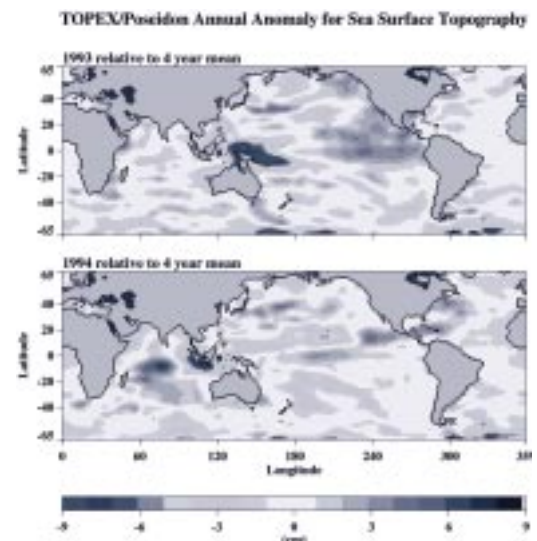
In addition, recent analyses are showing a previously unseen 9-month fluctuation in the strong ocean boundary currents, such as the Kuroshio current in the north Pacific, the Gulf Stream in the Atlantic, and the Agulhas current in the southern ocean. These fluctuations may be correlated with ocean bottom interactions. The causes for the fluctuations and their 9-month cycle are active areas of investigation.

Data from the TOPEX mission are being distributed by the Oceans and Ice Branch (Code 971) as part of a NASA Pathfinder effort to produce long-term data sets from earlier missions, such as Geosat, Seasat, and ERS-1. Reanalyses, based on new algorithms, are providing significant improvements in accuracy. Further information may be found at the Pathfinder homepage at <http://neptune.gsfc.nasa.gov/ocean.html> or the TOPEX Web page at <http://topex-www.jpl.nasa.gov>. An informational CD-ROM, entitled Perspectives on an Ocean Planet, is also available.

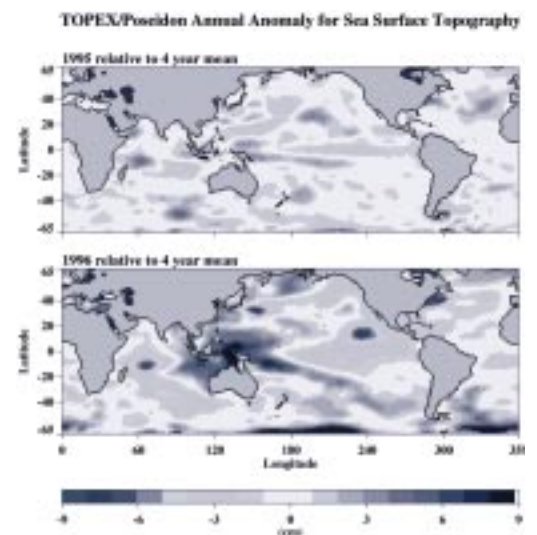
In an experimental effort to see if TOPEX data could be used to measure changes in the global mean sea level, early analyses indicated increases in sea level of as much as 4–5 mm/year, almost twice that obtained by using data from *in situ* tide gauges. However, a French team decomposed the

calibration algorithm and found an error in the radar measurement. The algorithm and the resultant data sets were corrected, and the data now show that sea level has remained relatively constant over the period of observation.

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The annual average anomalies of sea surface topography for 1993 and 1994 relative to a 1993-to-1996 4-year mean from TOPEX/Poseidon satellite altimeter measurements.



The annual average anomalies of sea surface topography for 1995 and 1996 relative to a 1993-to-1996 4-year mean from TOPEX/Poseidon satellite altimeter measurements.

It's Not Magic It's Data Assimilation

How can remote sensing scientists use data where no observations have been made? Providing such information is one of the goals of the Data Assimilation Office (DAO, Code 910.3), headed by Dr. Ricky Rood.

The DAO uses its Web site to provide information on—and background for—the data products that it generates. It includes the algorithm theoretical basis document (ATBD), which provides peer-reviewed documentation of the algorithms used for the data products. The following description of the DAO mission and approach is found on the DAO Web site (<http://dao.gsfc.nasa.gov/>).

“The ability to observe and understand the coupled Earth atmosphere/ocean/land-surface system depends on both collection of the data available from sources such as weather balloons, buoys, ships, airplanes, and satellites and on effective assembly of these data sets into a coherent global picture of the relevant environmental fields. Currently, data are gathered either as a matter of routine operations or for special research projects in a number of disciplines, including weather prediction, oceanography, and atmospheric chemistry. The data are scattered in space and time. The goal of the DAO is to integrate these data into a globally-coherent, common physical and chemical framework, and thereby, to substantially increase our information concerning the Earth system.

“One strategy for the construction of global, physically and chemically consistent data sets is data assimilation. Data assimilation allows forma-

tion of a time sequence of three-dimensional (3-D) pictures of the Earth system. The National Research Council has recognized data assimilation as a national priority in order to assure that maximum information is obtained from our observational systems.

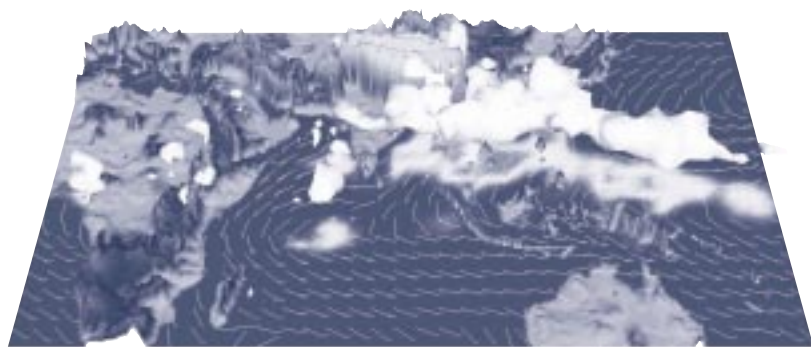
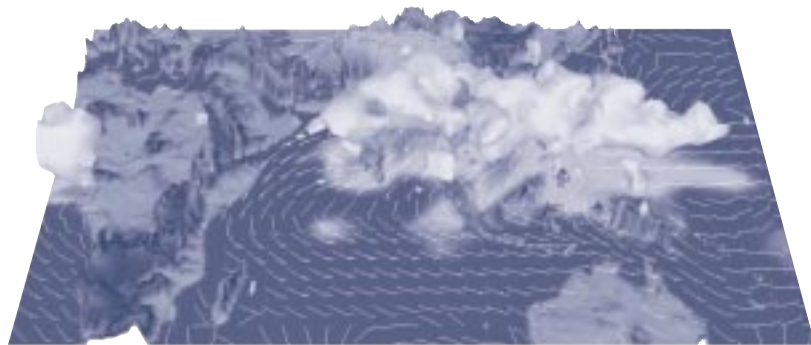
“Data assimilation is most highly developed in meteorology, particularly in weather forecasting. Improvements in assimilation techniques have been instrumental in improving the accuracy of weather forecasts, and the potential for assimilation techniques to advance our general understanding of the Earth system has already been demonstrated.”

Rood says, “Data assimilation (DA) is wrapped up in the notion that you have some sort of predictive model that tells you what to expect the system to look like; the model provides you with one source of information. You have observations of the system; that provides you another source of information. The idea is that you take the information from the predictive model and combine it with the information from the observations. If you know the error characteristics of the two sources, then your assimilated data set should be more accurate than either of them independently.” This enables researchers to obtain useful information where no observational data are available. Often, you can use one kind of data to develop information about a different physical process.

The challenges are great. Not only must a comprehensive picture of the operative physical phenomena and tremendous volumes of data be included in data assimilation systems,

but new ways of performing the computational analyses had to be developed. While there are many components to such systems, a major new component in the Goddard Earth Observing System (GEOS)-2 system is the objective analysis subsystem, which is where most current development work is underway. The objective analysis uses the physical space statistical analysis system and is designed to make the best use of the error characteristics of the forecast model and the observational data sets. It allows the data assimilation system to accommodate arbitrary error characteristics, an approach that differs from earlier, simpler systems that assume homogeneity in the error characteristics. The objective analysis approach will, ultimately, allow propagation of the errors in the flow fields under investigation, and will lead to better and more accurate analyses over longer times than are now available.

The objective analysis algorithm requires tremendous computing power and resources, the likes of which are unavailable even with the state-of-the-art resources currently available at Goddard. The objective analysis requires even more computing power than the predictive model, which is a consensus computational Grand Challenge. “In its purest form, the analysis ends up being a many-dimensional problem, and requires inversions of matrices that are much larger than any existing (or proposed) computer can accommodate,” says Rood. It’s not just computational speed, but also the ability to program for multiple processors, and being able to move information between proces-



Assimilation of the Asian Monsoon for June 1987 (above) and June 1988 (below). Superimposed over the orography are low-level winds (wind barbs) and contours of rainfall (in reds and yellows) and of the net heating of the atmosphere due to condensational and convective processes (in white). All quantities are monthly averages of the values assimilated by the GEOS-1 Data Assimilation System. The wind barbs represent the direction (from the tail to the head of the arrow) and speed (represented by a full barb for each 10 m/sec of speed and a half barb for an additional 5 m/sec) of winds located about 1/2 kilometer above mean sea level. The Indian Monsoon, as evidenced here by rainfall in the Bay of Bengal and by the speed of the Somali Jet (the oceanic winds just to the south and east of the Horn of Africa), was dramatically stronger in 1988 than in 1987.

sors when and as needed. Projections indicate a need for many hundreds of processors, all working in parallel, to provide the kind of support Rood feels is needed to do the job properly; current implementations use as few as 10–12 parallel processors.

As a result of the limitations on computing power, the DAO team has compromised on resolution. A lot of their customers would like to see development of a 1-degree- (or higher) [spatial] resolution model. The current system provides a 2-degree model. According to Rood, “Some people see this as a fundamental failure.” But, he explains, “we just do not have the computer resources to optimize the

code and to tune a 1-degree model.” Further, not everyone wants the same kind of product: Some customers want maximum time resolution, some want maximum space resolution. But, Rood adds, most customers would say that they would prefer a higher quality 2-degree analysis than a lower quality 1-degree analysis. “We are totally convinced that increased resolution is not the most cost-effective way to improve the quality of the assimilated data sets.”

A side effect of this emphasis on error characteristics and the need for advanced computing resources is the DAO team’s finding that because all observational data sets have their own

error characteristics, integration of new data sets into data assimilation system models is a non-trivial activity. As a result, early plans to integrate all available observational data into a grand assimilation system were unrealistic. The current approach is to target a few special observation sets that are small enough to deal with now, which are expected to address key scientific problems and for which resources can be obtained.

The DAO is already providing data products and support for NASA’s Mission to Planet Earth. During a series of stratosphere field missions, the DAO provided assimilation analyses that are central to the interpretation of the chemical observations. “This is also the place where we actually do some ‘weather’ forecasting,” said Rood. “We provide forecasts of the lower stratosphere that are used to guide the research airplanes to chemical targets.” In addition, the DAO has actively tried to provide prelaunch products for a wide variety of Earth science applications. Their first long-term assimilation, GEOS-1, has been used in studies of many climate and chemistry products. Rood noted that, “One thing we find is that as soon as users get the product, they try and push it to the edge, doing difficult problems where the uncertainties in the assimilated data are highest. This shows the great need for any information on many of the unobservable parameters in the Earth system.”

The Earth Observing System (EOS) is the primary driver for DAO activity. Formally, the first required delivery is for the AM-1 launch, scheduled for June 1998. For AM-1, there is a wide variety of expectations. Rood continued, “Right now, we are focusing on providing data products for instrument teams to help them improve their retrievals. Actual assimilation of AM-1 data will follow once the error characteristics of the new observations are known. The AM-1 platform offers

many challenges for assimilation, because the focus of the measurements is in disciplines where there is little heritage of assimilation. Aside from instrument team support, we expect that our analyses will be used very widely by Earth scientists not directly involved in AM-1."

Rood says that the DAO is "...very excited about some recent prototype precipitation assimilation experiments," and DAO expects to be heavily involved in the Tropical Rainfall Measuring Mission. DAO algorithms already have been extensively used in NASA Scatterometer (NSCAT) validation, where a recent example demonstrated the utility of the data assimilation system.

Results from the NSCAT on the Japanese Advanced Earth Observing System spacecraft (ADEOS) used numerical weather prediction for validation. The experiments showed that NSCAT data can improve weather forecasts in the Southern Hemisphere by more than 24 hours; in the Northern Hemisphere, the overall impact is less dramatic. But, during specific storms in the Northern Hemisphere, the NSCAT data can improve location of forecast storms by more than 1,000 km. Because of this rapid and successful validation, barely more than 6 months after launch, the NSCAT data are being used by NOAA for its ocean forecasts, which are used by the shipping industry. Based on this experience, Rood says that the prospects for EOS-era data to provide similar advances and refinement are excellent, and that data assimilation will become an excellent addition to the Earth scientists' analytical tool box.



Dr. Mitchell K. Hobish

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(Continued from "A Message from the Director of Earth Sciences")

Bob Langel has done as a world-renowned leader in the study of Earth's magnetic field for more than 35 years. His recent retirement from Goddard is a loss to the Goddard scientific community, but will not hinder analysis and application of his research efforts. The work of the Data Assimilation Office also supports the goal of becoming a Center of Excellence, in that the models generated there (based on data from various sources) serve to help explain and define phenomena that are hard or impossible to quantify in any other way. Ongoing education and outreach efforts continue to reinforce Code 900's commitment to national scientific literacy. We, in this case, have continuing requests for people to act as mentors for students, and I hope that people in the Directorate will take advantage of these opportunities whenever possible.

While support for the Center's Strategic Implementation Plan goals is by no means limited to Code 900 personnel, there are many more examples of the way Code 900 supports the Plan, certainly more than I can cite here. In the forthcoming weeks, the Directorate senior staff and I will be developing a Directorate Implementation Plan that adds more of the specifics required to ensure that everyone in the Directorate is able to carry out activities that respond to the Center's Plan and the Agency's Plan. It is evident that we have been and still are on the right track. I urge you all to read the existing Center Strategic Plan, look closely at the goals, strategies, and objectives laid out therein, make any inputs requested of you or that you wish to offer to the Directorate Implementation Plan, and make a personal commitment to continue your excellent efforts to help Goddard achieve success into the next century. It is those exemplary efforts you have made and continue to make that established the fine reputation we now have. From these efforts, we can continue to enhance our reputation as a Center of Excellence and a national resource enabling research and development in the Earth Sciences and related applications and spin-offs.



Dr. Compton J. Tucker:

Being in the Right Place at the Right Time With the Right Idea

Being bright and interested isn't always enough; you have to be at the right confluence of training, location, and people. Dr. Compton Tucker, of the Laboratory for Terrestrial Physics (Code 923), is one of the fortunate ones who, by dint of such synchronicity, has been able to parlay an unceasing interest in biology and ecological systems into significant contributions to the state of our understanding of these disciplines and their roles in biospheric sciences specifically, and Earth system science generally.



He wasn't always so focused. After obtaining an undergraduate degree from Colorado State University in "traditional biology," as he puts it, he worked in two banks and a greenhouse before responding to an announcement he saw in a student newspaper in Fort Collins, Colorado, for graduate assistants to work on a ground-based remote sensing project within a large interdisciplinary systems ecology program, the Grassland Biome of the U.S. International Biological Program. This was Tucker's first exposure to remotely sensed data and systems ecology. He says he "...somehow managed to stay with a demanding person to work with..." for his graduate work, and ended up obtaining both his master's and doctoral degrees in the same program. Tucker's work involved analyzing high-resolution spectrometer data from the Pawnee National Grasslands, understanding the relationships between grass canopy spectral reflectances and the chlorophyll, liquid water content, green biomass, dry biomass, and total wet biomass present in grass canopies.

The rest, as they say, is history. As Tucker puts it, "In retrospect, it was that understanding, as well as modeling the same in a biophysical sense, that provided me the insights to use remotely sensed data either at very small scales—at the level of meter-by-meter—or at much larger scales, using satellite data."

Tucker came to Goddard in 1975 on a National Research Council postdoctoral fellowship. His first year or two here were spent reviewing his doctoral work and publishing papers on those studies, and extending the basic approach in an environment that encouraged systems thinking and applying those concepts to satellite data. In 1977, he became a civil servant, and led a series of field experiments in collaboration with other investigators at the Beltsville Agricultural Research Center, which further extended some of these techniques for non-destructive estimates of primary production. His then branch head, Charlie Schnetzler, and Louis Walter, who was at that time the laboratory chief, kept

pushing him, suggesting that he extrapolate his approach to satellite data.

In 1980, he found that the only satellites then capable of applying such techniques in the time domain were the NOAA-series of meteorological satellites. Contact with the right people—such as James Gatlin, who was then branch chief in Code 970—led to some things that worked, and worked well. Gatlin was an engineer, and he eventually went on to Code 700, but Tucker and his coworkers pushed ahead in Code 900 and found a goldmine in time-series remote sensing using the coarse-resolution data that they received every day, and then combined to minimize clouds to allow them to examine ground phenomena. Using this approach, they could look at primary production in many of the same processes that Tucker had been studying as a graduate student, albeit at continental and global scales. Tucker says, simply, "It is just a modification of the technique, only applied from space, as opposed to holding some instrument in your hand, or using a spectrometer on the ground. It is unusual when the same satellite technique is used to quantify aspects of the global carbon cycle while also providing real-time information as early warning of famine in Africa, yet that is exactly what we have been doing the past 10 years." But it took the right approach and being with the right people at the right place to make it happen.

Tucker claims that his data needs don't require sophisticated instrumentation, but are, rather, very dependent on limited (but well-defined) spectral regions, and an emphasis on long-term daily observations, continuity of observations in time, and sufficient computational resources to process the resulting satellite data. He has some interest in designing and building sensors and instruments, and his work has influenced the use and design of

many state-of-the-art instruments, including Landsat's Thematic Mapper (TM), the Advanced Very High Resolution Radiometer (AVHRR), and the EOS-era Moderate Resolution Imaging Spectroradiometer (MODIS). His first exposure to Landsat work was under the guidance of the late Bill Nordberg.

Tucker's self-described relatively simple approach has taken him into the study of several areas that are amenable to such techniques. He studies tropical deforestation and habitat fragmentation, because such studies—regardless of the scale—take advantage of specified spectral resolution. This is because certain bands are very useful for some investigations of specific processes, and those processes are almost always coupled with properties of the surface, including vegetation, soil, or water, for example. His early grassland biomass estimation studies have taken him not only to Colorado, but also to several places in Maryland, the United Kingdom, Iceland, Sweden, and France. These studies have been extended and expanded to include other areas of interest, such as the Amazon Basin, the African Sahel, the Pacific Northwest, and the deserts and steppes of Central Asia, including Mongolia. As a result of these studies, Tucker has gained an international reputation, and has even been made an honorary member of the Mongolian Academy of Sciences, along with Dr. Mary Cleave (the current project manager for SeaWiFS), with whom he visited Mongolia in 1995. Both received the Mongolian Medal of Friendship at that time. The Mongolian work involved the construction and operation of a NOAA satellite ground station, built largely out of NASA surplus equipment, and run by the Mongolians. The AVHRR data received by the station are used by the Mongolian Government for planning purposes, and are also shipped on tape to Tucker for his own research on the

expansion and contraction of desert areas.

With all of his activities, Tucker finds himself increasingly drawn into management activities, if only to address the many areas of research in which he's interested. He says, "I realize the value of having graduate students. As you start down several areas of research and find one or more that work well, that you can do yourself, you subsequently find quickly that to extend this to the next step requires someone else working with you. That's probably my greatest frustration: That there just isn't enough time to work on all the things that I'm interested in, and to actually do the majority of the work myself." As a result, he's involved in a large project at the University of Maryland analyzing satellite data for the entire non-Brazilian Amazon—Bolivia, Peru, Ecuador, Colombia, Venezuela, and the Guyanas—where he is involved with very capable undergraduate and graduate students who analyze the images. He and other senior scientists interact with the students and review what they do. Tucker refers to this as an example of an "industrial-scale scientific enterprise" due to the volume of satellite data analyzed.

In 1995, Tucker received the William Nordberg Memorial Award for Earth Science, "...which is given annually to an employee of the Goddard Space Flight Center who best exhibits those qualities of broad scientific perspective, enthusiastic programmatic and technical leadership on the national and internal levels, wide recognition by peers, and substantial research accomplishments in understanding Earth system processes which exemplified Dr. Nordberg's own career." Prior to winning the Nordberg Award, Tucker received the Henry Shaw Medal from the Missouri Botanical Garden in 1992, and the Air and Space Museum Trophy for Current Achievement in 1993.

Clearly, Tucker was an obvious candidate for such recognition, although he takes a modest approach to his own success, describing himself as a "mediocre jockey with the luck to draw a very fast horse." The speed of that horse is a direct function of his own intellectual drive, the people with whom he feels he has been privileged to work, having the right ideas at the right time, and the right place to explore those ideas. The people include a group of scientists and engineers with whom he worked during his graduate career, but he credits the Goddard environment with much of his success. As he put it, "If I hadn't been situated at the Goddard Space Flight Center, the work I've been able to do simply never would have congealed. Here at Goddard I've been very fortunate that my directors, laboratory chiefs, and branch heads were very supportive, and insulated me from a lot of things that could have been distractive. They were encouraging and also pushing, saying, 'Why don't you do this; why don't you do that; work in this general area.' I've been fortunate to work with many good scientists and engineers, and most of those have been at or affiliated with the Goddard Space Flight Center. I consider myself very fortunate to have been able to work with so many talented, pleasant, and dedicated people at the Goddard Space Flight Center."

Tucker has enjoyed considerable success, and has contributed much in the applications of space technology to understanding and preserving our biosphere. He is an excellent example of the skills and talent available as a national and international resource that are found at Goddard.



Dr. Mitchell K. Hobish

Can *You* Trust Your Data?

With the launch of a five-instrument, low-Earth-orbit platform in 1998, NASA and the world will embark upon a multiyear program of Earth observations that will provide data to allow us to ask—and answer—basic questions about the state of our home planet’s interacting physical and biological systems. The Earth Observing System (EOS) will take advantage of a time- and space-staggered array of instruments on orbit, *in situ* air-, ground-, and sea-based measurements, and computer-based modeling to address questions of global change and possible human contributions to such changes. The instruments, platforms, and launch vehicles all have significant lineage; the probability for success is extremely high. But what we lack is a history of providing the tools to allow the construction of 15-year-plus-long data sets that are continuous and contiguous, and that can be “married” to existing Pathfinder data sets. Since we are looking for potentially small changes over long time periods, the ability to stitch these data sets together takes on great significance.

It falls to a group of dedicated, talented, and energetic people at Goddard to provide the leadership and the tools necessary for this marriage to succeed. The teams in the Space Geodesy Networks and Sensor Calibration Office (Code 920.1), headed by Mr. John Bosworth, are not often visible to the scientific community, but their charge is key to this whole enterprise.

Representatives of the Office have significant impact on the whole EOS enterprise, with roles ranging from EOS Calibration Scientist (Dr. Jim Butler), who reports directly to the

EOS Senior Project Scientist (Dr. Michael King), to leader of the MODIS Characterization Support Team (MCST; Dr. Bruce Guenther), to coordinator of some of the calibration labs (Dr. Peter Abel). But these more-visible people are but the advance guard, with a technical staff that, for the MCST, for example, constitutes a tightly integrated team of civil servants and contractors, all of whom carry significant responsibility in ensuring that the scientists behind the EOS program can provide the required long-term, continuous data sets.

Calibration is considered so important that requirements were levied on proposing organizations as far back as the original Announcement of Opportunity, issued in 1988. As Guenther put it, “We must be able to relate data from the beginning of the study to data at the end of the study, so it’s necessary to keep track of how much of what you’re observing might be instrument artifacts, how much of it might be scale differences, and how much is really observed in the science.” Without appropriate calibration, this would be impossible.

Not every calibration activity will be accomplished prelaunch, on the ground, however. In an effort to improve the long-term consistency and quality of the data and to reduce overall costs, some calibration activities will be performed in the on-orbit era. For example, the United States Geological Survey (USGS) and Northern Arizona University are making radiometric measurements of the Moon with the goal of producing a lunar radiometric data set that can be used by EOS and other satellite sensors for on-orbit calibration. These data will allow scientists to maintain



The GSFC 48-in hemispherical source is shown during the calibration of the SPOT 2 Sensors in the Matra Laboratory in Toulouse, France.

calibration activities throughout the EOS era, and to allow data obtained by EOS-era instruments to be correlated with data obtained by other sensors, as long as those sensors take measurements of sunlight reflected from the Moon’s surface, as is being planned for SeaWiFS, ASTER, and MODIS, for example.

Calibration activities, by their very nature, require tying sensor and instrument characterization and calibration back to national standards laboratories. As a result, there is significant interaction with the National Institute of Standards and Technology (NIST) in this country and, because EOS is inherently international in scope, with other standards labs internationally. The opportunities for cross-organizational and international interactions are, as a result, manifold, and serve to point up the cooperative nature of EOS. This cooperation requires the involvement of government, university, and industry representatives in a long-term program consisting of peer-reviews,

(Continue on page 20)

Earth System Science Pathfinder Mission Selected

The Earth System Science Pathfinder, or ESSP Program, was initiated to infuse new opportunities for focused, science-driven, Earth-orbital missions into the broader Mission to Planet Earth (MTPE) enterprise. As such, ESSP missions were solicited, via an open Announcement of Opportunity (AO), under the conditions that they must be launch-ready in 3 years, that the NASA cost for the first mission selected must be less than \$60 M, and that the NASA cost for the second mission it must be less than \$90 M. In addition, under the rules established for the initial ESSP AO, investigations were solicited under Principal Investigator or PI Mode, in which the PI is the focal point of responsibility for mission success. The aim of the ESSP program is to provide frequent opportunities for Earth System Science investigations involving new partnerships between university scientists, NASA Center scientists, engineers, and managers, other Federal laboratories, and Industry. Emerging science questions not foreseen when the EOS Program was devised and implemented 7 or more years ago are natural targets for early ESSP missions.

In contrast with NASA's technology-focused New Millennium Program, the ESSP Program successfully incorporated a traditional and exhaustive scientific peer review into the selection process for entire space flight missions, in a "cradle-to-grave" sense. Scientific investigations in all strategic areas of Earth System Science were solicited, although it was stipulated in the initial ESSP AO that missions were to demonstrate their ability to complement to

EOS flight programs as well as to other approved MTPE flight programs.

A two-step evaluation process was implemented for ESSP. Step One, a peer evaluation driven by science, was used to encourage those proposals with the strongest endorsement by the broad Earth Science community. Only those proposals which received a strong endorsement from the Step One Science Peer Panel were encouraged to submit comprehensive Step Two proposals in which extensive information pertaining to cost, management procedures, opportunity and outreach, and technical approach, as well as scientific objectives was required. Out of a total of 44 Step One proposals, 13 were encouraged to submit full proposals, of which 12 complete proposals were received for review in mid-December 1996. An evaluation panel chaired by NASA Headquarters Office of Mission to Planet Earth members conducted a comprehensive review of the proposed missions' science, technical approach, management, cost realism, and opportunity/outreach. After a 10-week review cycle involving multiple plenary meetings, the findings of the Evaluation Panel were presented to W. T. Townsend, the Acting Associate Administrator for Mission to Planet Earth at NASA Headquarters. As outlined in the AO, two primary missions and one alternate were selected. Dr. Townsend announced

his selections at a press conference in late March 1997.

The initial ESSP mission is entitled the "Vegetation Canopy Lidar," or VCL, under the leadership of Prof. Ralph Dubayah of the University of Maryland at College Park. This innovative mission employs an array of five laser transmitters and a 90-cm diameter telescope to directly measure the vertical structure of the Earth's land-cover and land surface using a method pioneered in aircraft and space by Code 900 scientists and engineers (i.e., Shuttle Laser Altimeter (SLA) on STS-72 in January 1996). VCL will provide a never-before-possible inventory of the heights of forest canopies and their spatial variability on a global basis, while also developing a global network of up to one billion topographic ground control points in a geodetic reference frame. VCL teaming partners include OMITRON, CTA Space Systems, Fibretek, and Optical Corporation of America (OCA). Code 900 scientists and engineers are responsible for supplying the multibeam laser altimeter (MBLA) instrument, for instrument science, aspects of data calibration and validation, and for precision orbit determination. Key Code 900 players on VCL include Dr. Jack Bufton (920), Dr. Robert Knox (923), Dr. J. Bryan Blair (924), and Dr. J. Andrew Marshall (926). The technologies that are part of the VCL primary instrument (MBLA) are an outgrowth of NASA GSFC (and Code 900) efforts with the Mars Orbital Laser Altimeter (MOLA), the Shuttle Laser Altimeter (SLA), and the Geoscience Laser Altimeter System (GLAS), as well as with advanced airborne laser systems. VCL's contribution to global ecology and land-cover-change studies could well have the same sort of impact that Landsat-1 (ERTS-1) had for global Earth land surface studies in the early 1970's.

VCL is scheduled for launch in early 2000, with a 2-year operational lifetime. Seasonal coverage of all of the Earth's

major forests will be possible with the data to be acquired by means of this mission. As with all ESSP missions, NASA will initiate a Science Data Analysis Program or SDAP in late 1999 to provide opportunities for research using the datasets to be generated by VCL. This SDAP will be released in the form of a NASA Research Announcement just prior to launch.

The second ESSP mission selected is the "Gravity Recovery and Climate Experiment," or GRACE, under the leadership of Professor Byron Tapley of the University of Texas at Austin. This remarkable mission is to employ two small satellites in lower Earth orbit to measure the time-varying nature of the Earth's gravity field in order to characterize global ocean circulation and to provide new insights into large-scale continental aquifers. By teaming with colleagues in Germany, under the leadership of Dr. C. Reigber (GFZ), the GRACE mission is scheduled to reach Earth orbit in 2001 by means of a COSMOS launch vehicle. GRACE achieves its high resolution of the Earth's ever-so-slightly-changing gravity field, or geoid, by measuring the range-rate between its two satellites using a highly precise microwave tracking system, together with state-of-the-art accelerometers and GPS receivers. GRACE is a natural outgrowth of the CHAMP mission, now slated for space flight in 1999 by the German Space Agency. Teaming Partners on GRACE include Loral Space Systems, JPL, the JHU Applied Physics Laboratory, ONERA (France), DLR (Germany), and GFZ (Germany).

Code 900 scientists have been involved with studies of gravity fields for 25 years or more, and many of these scientists are delighted with the selection of an advanced gravity mission with a lifetime (5 years) long enough to study the time-variable geoid and with which to retrospec-

tively analyze ocean radar altimeter datasets extending back to the 1970's.

The ESSP Alternate mission is entitled "Chemistry and Circulation Occultation Spectroscopy Mission," or CCOSM. This atmospheric chemistry mission is under the leadership of Professor Michael Prather of the University of California at Irvine, and includes a science team consisting of many of the world's experts in atmospheric photochemistry and modeling. Dr. Anne Douglas of NASA's GSFC is a team member on this innovative mission. CCOSM seeks to provide never-before-available global measurements of over 30 trace gas species in the middle to lower atmosphere using a method known as solar occultation spectroscopy. The objectives of CCOSM are to provide an improved understanding of how atmospheric circulation controls the evolution of key trace gases and aerosols and how they might provide insight into atmospheric pollution monitoring and modeling. Key teaming partners on CCOSM include JPL, Lockheed Martin IR Systems, and Spectrum Astro Corporation. The CCOSM mission design owes its heritage to the extremely successful ATMOS experiment on the Space Shuttle. Should either of the primary ESSP missions suffer cost or schedule difficulties, CCOSM would be activated as a "hot back-up."

The ESSP program is a living one, and a second ESSP Announcement of Opportunity is slated for release in mid-1998. The plan is to release AO's soliciting ESSP missions every two years so that an annual rate of one launch per year can be achieved within the ESSP budget by 2000. The ESSP Project is managed at GSFC under Project Manager Nick Chrissotimos (Code 408) for NASA's Office of Mission to Planet Earth.

Jim Garvin, Guest writer

(Continued from UARS' Amazing Journey, page 2)

observations by PEM have shown that most of the relativistic electrons observed at geosynchronous altitudes (by GOES, for example) are trapped. Only about 1–10 % of the relativistic electron precipitations (REPs) measured at geosynchronous altitudes actually precipitate into Earth's atmosphere. These measurements thus show that REP's have a relatively small global impact on stratospheric odd nitrogen, which was a subject of controversy before the UARS launch.

Upper tropospheric water vapor in the presence of clouds. The MLS team noticed after launch that they were getting some spectral interference from water vapor. Further analysis showed that they could use the MLS instrument to actually measure upper tropospheric water. Since MLS is a microwave emission instrument, the measurements could be made even if ice clouds were present. This new water vapor measurement is currently being used to study how cirrus clouds affect the climate.

According to Project Scientist Dr. Mark Schoeberl, the UARS mission will probably run until the spacecraft or most of the instruments fail, or until there no longer is enough power to run most of the instruments. If the spacecraft continues on as it has, the project will certainly last beyond the millennium—maybe longer.

Kathy Pedelty



Studying Magnetic Fields

When you hear the term “magnetic field” what pops into your head? An image of a bar magnet you played with in high school? The horseshoe magnet you had when you were a kid (and maybe still have somewhere)? Or perhaps an occasional article about the effect of magnetic fields on migratory birds and fish? Whatever the image, chances are you do not think about Earth’s magnetic field in all of its components, nor do you think about devising and building satellites to detect that field. But recently retired Geodynamics Branch geophysicist Bob Langel does. In fact, Langel is world renowned in the field of geomagnetics, with his models and maps of Earth’s magnetic fields still being used as standard references today. When he retired in January after 37 years in the workforce (almost 35 of them here at Goddard), Langel’s colleagues paid him tributes ranging from poems to heartfelt speeches and testimonials, all of them well deserved.

Over his time at Goddard, Bob Langel designed the Magsat mission to measure Earth’s magnetic field and changes to that field due to solar effects. The data and information that came from this satellite contributed to United States Geological Survey charts of Earth’s magnetic field. Magsat provided a wealth of information about Earth’s crust and core, albeit at a point in time. Magsat was to be one of several satellites designed to allow for a long time series of magnetic field measurements. As is common among satellite programs, however, those other missions never took place. Without the long time series of magnetic field data measured from space, scientists such as Langel are still in the position of having to extrapolate

via models to show what they think happens.

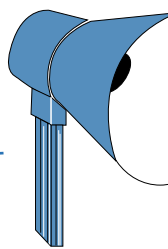
Besides the lack of trend data, there is also the question of resolution. The more information that can be obtained about magnetic features of all sizes, the more complete the models will be. Some of the geological formations that scientists want to study are too large or too small to be adequately measured from orbit. Aircraft, for example, generally fly at 3 km, which is a good distance from which to detect formations such as ore bodies and deposits. Satellites, on the other hand, cannot generally resolve formations smaller than mountain ranges. What is needed is a good way to measure the midrange features—smaller than a mountain range and larger than an ore deposit. Magnetic field detectors flying on the shuttle proved that such measurements could be taken, but shuttles do not stay on orbit long enough. Hopefully, a new Danish satellite, Oersted, on which Langel is the co-principal investigator, will bridge some of these gaps to take magnetic field measurements over a long time span.

While Magsat set the standard at the time, there is still much that is not known about the extent and effect of Earth’s crustal field. Langel and several of his associates at Goddard recently completed a study that provided a sophisticated model of the magnetic field from the surface of Earth to an altitude of about 2,000 km. The Earth’s magnetic field is actually composed of a field emanating from the planet’s molten center, the core or main field, a field from currents in the ionosphere, a field from currents in the magnetosphere, and a crustal field, emanating from the 40 km or so of

rock on the surface of the planet. The crustal field is a relatively small component of the total field (about 2,000 times weaker than the core field—somewhat like the difference between a search light and a small Christmas tree light). The main field is what affects compasses and migratory birds, and is what scientists see evidence of in drill samples from the bottom of the ocean. One of the problems in studying the crustal field lies in the difficulty in separating it from the fields from other sources. The idea for the model stemmed from the speculation that a comprehensive model would be the best way to identify and describe the various fields. Previous models have included both the core and magnetospheric fields, but this is the first model to also incorporate representation of the ionospheric field.

The first problem in building such a model is acquiring adequate data. For this model, the scientists used data from four satellites and from magnetic observatories at Earth’s surface. The four satellites are the three POGO’s (OGO-2, -4, and -6), which acquired data from October 1965 through July 1971, and Magsat, which acquired data from November 1979 through mid-May 1980. Data from POGO are limited because they are of the field magnitude only; data from Magsat are limited because they are acquired only at dawn and dusk local times. Also included are selected hourly average data from magnetic observatories at the Earth’s surface. To further complicate matters, each of the field sources is organized in difference coordinate systems, so the second problem was making sure that all the

(Continue on page 20)



SPOTLIGHT *on Education*

Education Efforts Underway at Goddard

It is a pleasure to communicate with the Earth science community through this newsletter and to have an opportunity to acquaint each of you with the services of the Education Office. Let me begin by noting that the Education Office views itself as directly linked to the implementation of the new GSFC Strategic Plan, especially in the area of Goal 3, enhancing scientific literacy. This goal is particularly important given recent statistics on the need for improvement in science and mathematics performance by American schools. The most recent Third International Mathematics and Science Study of nations throughout the world has provided some revealing information on the quantity but lack of depth of coverage in areas of science and mathematics. Scientific literacy is not a remedial concept, however. It is, in the words of the National Science Standards: "the knowledge and understanding of scientific concepts and processes required for decision making, participation in civic and cultural affairs, and economic productivity. People who are scientifically literate can ask, find, or determine answers to questions about everyday experiences. They are able to describe, explain, and predict natural phenomena." (Introducing the National Science Standards, p. 5.)

The national science standards developed through the National Research Council and being implemented by virtually every school in the country specifically identify Earth and space sciences as crucial areas of study. It is also virtually accepted that GSFC is the Earth science capital of the world, and that places a heavy burden on us, not only to provide high-quality science, but to provide successful

translation of that science so that it can be communicated to teachers and students alike.

Given this orientation, several programs are worthy of note. We have been asked by Prince Georges County schools to provide them with assistance as they seek to revise their Earth science curriculum. Their request is to be able to review their criticism to ensure that what they develop is state of the art and exposes students to substantial and accurate information.

Additionally, we are developing a relationship with the community college sector and hope to establish a strong working relationship through which community college faculty will be able to spend a semester with us for the express purpose of understanding and incorporating remote sensing data into their current instructional practices.

We are also participants in the KIDSAT program, a national NASA program for middle school students in, initially, 17 middle schools, growing to 40 in the coming school year. The program allows students to design research projects that are based upon photographs taken by the astronauts on designated shuttle missions. The students establish a mission control environment through the University of California, San Diego, under the leadership of Sally Ride. Each school site then establishes its own control center in which the team determines the pictures they will be requesting based on the shuttle orbit, forecasting the weather conditions at the time the image will be taken, and submitting the requests for approval. GSFC Education is working with Baltimore

City's Canton Middle School students on the program. This fall, Baltimore City College High School will join Canton and provide a mentoring opportunity for college-bound high school students to link with middle school students to enhance the program. GSFC Education is also bringing the two lead teachers for the program to GSFC this summer in order that they can more directly link MTPE and Landsat data to the project.

Also, this summer we will be sponsoring a 1-week workshop with the National Science Teachers Association that will incorporate MTPE training as well as GLOBE participation as a major follow up activity throughout the school year. This program will focus on 5 teams of 5 educators from urban schools as part of our urban initiative.

Additionally, this summer the highly successful Maryland Ambassadors Program will shift from a teacher training focus to a curriculum support one. Twenty of the seventy Ambassadors who have been trained over the past 3 years will return for 4 weeks to create Earth system science investigations that both utilize and will be disseminated via the Internet. We hope that each team will have at least one Earth scientist to assist them in the project. Anyone interested in participating can contact either me or Dr. Dick Hartle, the Education Council representative for Code 900.

One final effort in the area of Earth and space sciences is occurring in the State of Maryland. The State Board of Education has approved a new high school assessment program that includes Core Learning Goals in Earth and space sciences. These new assessments will be part of new graduation requirements, intended to affect the graduating class of 2005. GSFC is working with the Maryland Space Grant Consortium, the Maryland State Department of Education, and local school systems to identify

(Continued from *Education Effort Underway at Goddard*)

ways in which GSFC can help meet the enormous personnel training needs in Earth science related to this requirement.

In closing, as the summer months approach, the Education Office is in constant need of individual scientists, engineers, and technologists who would be willing to share their work with either students or teachers. Such sharing is consistent with the Center Director's emphasis on outreach as exemplified in the GSFC appraisal system. Please feel free to contact us at 6-7205 should you wish more information or be willing to provide assistance in the rewarding world of education, thereby affecting future generations. It has often been said that youth is our country's most important natural resource. Please consider joining us in developing that resource.



Robert Gabrys, Guest writer

A Global Change Master Directory (GCMD) staff member has begun participating as a volunteer mentor for the Kids as Global Scientists program at the University of Colorado, Boulder. This is a World Wide Web-based bulletin board where children and professionals can interact in discussing global scientific issues. The URL is <http://www-kgs.colorado.edu/>.

* * *

The Scientific Visualization Studio, together with Tweedie and Associates, has completed an educational multimedia CD-ROM on the Asian Monsoon. The CD shows how observations, global models, and computers are used to develop a scientific understanding of the Asian monsoon. The text is written with the intent of stimulating high school students toward their own related investigations through the use of software and data provided on the CD. The CD, which has been under development for more than 18 months, is currently being evaluated by Junior and Senior High Earth science educators. (For more information please contact Sara Tweedie (933-7812) or Cindy Starr (286-4583).

* * *

A three-pronged effort to study Viking and future MGO data of Mars in the schools is in the planning stages via work being done by Dr. Maria Zuber at MIT, Stephanie Stockman for a Howard County middle school, and Lawrence Jessie at P.G. Community College. Mr. Jessie, an adjunct professor at P.G.C.C. will introduce Mars and Earth Comparative Studies in the next semester astronomy laboratory that he teaches.

* * *

Dr. Elissa Levine was interviewed by *Kiwanis Magazine and International Business Journal* about her involvement as a NASA scientist with the GLOBE program. Topics included information about the GLOBE program in general, its importance for the scientific community, and specifics about how Dr. Levine has participated in developing measurements and learning activities, conducted training, and will use the data generated by GLOBE students. The article is scheduled to be published some time this spring. Information on the GLOBE project student data provided by Elissa Levine will be used in a briefing to the U.S. Secretary of State.

* * *

The Goddard DAAC presented five teacher workshops and distributed educational materials at the Satellites and Education Conference IX in West Chester, PA, on March 12-14, 1997. Four workshops demonstrated the remote sensing tutorial and freeware for the first in a series of Earth System Science Educational products being developed on the topics of Ozone, Global Vegetation, and Ocean Color. The fifth workshop demonstrated how to understand and interpret satellite images of TOMS total column ozone data, AVHRR NDVI data, and CZCS Ocean color data.



(Continued from *TOPEX/Poseidon Mission*, page 4)

Dr. Chet Koblinsky, branch head at Code 971, emphasizes that the primary TOPEX mission is to observe the major ocean basins and to detect fluctuations in topography and in the circulation. These measurements are made with a precision of better than 5 cm. Given that the satellite flies at an altitude of 1,336 km (830 miles), this is comparable to being able to detect less than the width of a U.S. dime on the surface of the ocean from a jet flying at 35,000 feet! Large-scale interannual variations in sea level are emerging that show basinwide undulations associated with major shifts in global air-sea interaction and ocean circulation patterns (see accompanying figures.) These processes are the focus of several studies within the Oceans and Ice Branch.

TOPEX/Poseidon's 3-year prime mission ended in fall 1995; the satellite is now in its extended observational phase. Building on the existing close working relationships between NASA and CNES scientists, a follow-on mission is being developed with CNES. This mission is called Jason-1, and is due to be launched in late 1999 or early 2000. Jason will continue this program of long-term observations of ocean circulation from space into the next century. Goddard's Code 971 will continue building models and analyzing data obtained from TOPEX and Jason measurements and blend them with observations of ocean surface winds from NSCAT, ocean color and productivity from SeaWiFS, rainfall from TRMM, and sea-surface temperature from MODIS for studies of the ocean-atmosphere system.



**Kathy Pedelty and
Dr. Mitchell K. Hobish**

Multicultural Diversity in the Earth Sciences Directorate: Excerpts from the Earth Sciences Directorate Multicultural Diversity Plan

Code 900 now has a Multicultural Diversity Plan in place. More information can be obtained from the Code 900 Web site or by contacting one of the committee members listed below. The following is taken from the Directorate Plan:

Dimension of Diversity

In the Earth Sciences Directorate, the dimension of “diversity” indicates that the Directorate employees represent various backgrounds consisting, for example, of customs, beliefs, religions, languages, knowledge, values, physical ability, and social characteristics. The composite of these elements defines a myriad of cultural groups with unique talents and capabilities. Cultural groups include, but are not limited to, ethnic and racial groups. Within each group may be found further subsets based on class, age, gender, and regional differences, to name a few. Each group and subgroup represents a talent pool whose contributions are to be affirmed equitably and respectfully.

Definition of Multiculturalism

Multiculturalism is that attitude in an organization that provides an environment free of discrimination and barriers in which all individuals

who represent America’s great diversity have the opportunity to develop, participate, and contribute fairly and equitably. This includes actions to ensure a responsible attitude toward multiculturalism that influences all policies, processes, and procedures. Multiculturalism provides a forum for all individuals to recognize, appreciate, value, and be cognizant of diversity, thereby promoting trust, enhancing communication, and nurturing respect and concern for the welfare of all individuals within the organization. It creates a work environment in which management and all employees are aware of and responsive to diversity, the individual in the workforce feels valued, and each talent may be fully utilized and each potential fully realized.

Section IV—Cultural Diversity Advisory Committee

The Earth Sciences Directorate will continue to support a Cultural Diversity Advisory Committee that will be composed of no more than eight members representative of the Directorate organizations and cultures. The Committee and Directorate Management will work together to fulfill the Goals of the Directorate Multicultural Plan. In particular, the Committee will:

- advise Management on detailed steps to be taken in achieving the Directorate Multicultural Plan’s goals
- continually assess the effectiveness of these steps
- evaluate the professional status of the varying cultures in the Directorate, considering if there are any common problems and/or opportunities to address problems
- report to Directorate Management on these matters at least twice a year, or more, as situations dictate
- coordinate with Goddard’s Multicultural Advisory Team (MCAT)
- partner with contractor management to emphasize the Director’s commitment to multi-cultural diversity.

The current committee consists of:

J. Marshall Shepherd, Code 912
Blanche Meeson, Code 902.2
Al Chang, Code 974
Ann Mecherikunnel, Code 925
Emily Michaud, Code 940
Michael Jasinski, Code 974
James Harrington (Center MCAT), Code 933



Education and Outreach

Lawrence Jessie (Code 920) participated in a science/technology career fair on December 5, 1996, at the Queen Ann School in Bowie, MD. Students in grades six to twelve visited with representatives of a broad spectrum of professions for this half-day affair. Larry presented his view of Earth science career opportunities and provided the science staff with a copious supply of NASA educational materials.

Jessie also will be a judge at the Eleanor Roosevelt High School 1997 science fair. This is Larry's fourth annual E.R.H.S science fair activity.

Jessie participated in a technology-oriented Communications Fair on March 8, 1997, and a Science Fair on March 11, at the Kettering Elementary School near Bowie. Students in grades K–6 participated in Earth/space demonstrations and exhibits during these two half-day affairs. Larry presented his views of Earth and space science and provided a copious supply of NASA educational materials to parents, teachers and students.

William Webster (Code 920) was a judge at the Seabrook Elementary School Science Fair on February 7, 1997.

1997 Society for the Advancement of Materials and Process Engineering (SAMPE), Boston Chapter/GSFC "Boston Marathon" School Visit Program — This year's visit by Webster concentrated on schools in rural New Hampshire. Presentations and discussions were given to classes ranging from pre-first grade to eighth grade. Presentations covered planetary science and a review of the two missions now on their way to Mars. In view of the interest in comet Hale-Bopp, Will also gave several presentations on comets and the Halley flybys of 1986.

Several Global Change Master Directory (GCMD) staff members represented the GCMD at the Eleanor Roosevelt High School Science Fair. Many of the projects were very advanced for the high school level again this year. Students and faculty were very appreciative of the NASA outreach efforts.

Robert Bindschadler (Code 971) gave a talk to Holy Trinity Episcopal Day School in Bowie on February 7, 1997, on his experiences as an Antarctic scientist.

Dr. Jim Heirtzler (Code 920) gave Earth Science lectures at Wilde Lake High School, Columbia, MD on March 24.

Lisa Bernard (Code 931) was invited to serve as the NASA representative on the Maryland Business Roundtable for Education Technology Oversight Committee as a result of GSFC's experience and success with the Maryland Teacher Ambassador Program.

Goddard DAAC staff conducted two workshops on the use of remote sensing data and information within the classroom (one for grades 6–12, the other grades 13–16) at the National Science Teachers Association meetings in New Orleans, April 3–4. One workshop was carried out in partnership with Discover Earth and teachers from Delaware and New York State.

Condolences to:

Linda Baumann (Code 900) and her husband, Bob, on the loss of his father, Bill Baumann, on January 25, 1997.

Cindy Lewis (Code 910) on the loss of her father, Jess Lewis, on February 24, and the loss of her grandmother, Evelyn Lewis, on March 14, 1997.

Aleta Johnson and her husband, Bob, on the loss of her mother, Eva Marie Criswell, on May 13, 1997.

Our deepest sympathy to the family and friends of Cheryll Madison who passed away on May 3, 1997. As an employee of Hughes STX, Cheryll provided assistance to the Manager of Education Programs for the educational outreach activities of the Earth Sciences Directorate. She was the Assistant Editor for the Directorate's newsletter on educational activities, "Eyes on Earth Education." Cheryll was very active in planning presentations, visits, and field trips, as well as supporting meetings, conferences, and collaborative projects with educators, school systems, colleges, agencies, NASA, and GSFC. She will be missed.

Get Well Wishes:

Our prayers and get well wishes to Piers Sellers' son, who is undergoing cancer treatment.

Congratulations to—Births

Barbara Conboy (Code 920) and her husband, Jack, on the birth of their daughter, Sara Lynn, on May 30, 1996.

Adina Tarshish (Code 930) and her husband, Sam, on the birth of their son, Eli, on December 20, 1996.

David Considine (ARC, Code 916) and his wife, Debra, on the birth of their daughter, Marisa Simone, on December 25, 1996.

Jim Kalshoven (Code 924) and his wife, Laura, on the birth of their daughter, Josephine Marie, on February 25, 1997.

Jiyu Shan (IDS, Code 902) and his wife, Aijun, on the birth of their son Tim Tianyu, on March 31, 1997.

Congratulations to—Marriages

Kellie Scialabba (GSC, Code 970.2) on her marriage to Mark Reubens on February 7, 1997.

Honors and Awards

1997 Recipients of the NASA Honor Awards:

Equal Employment Opportunity Medal	Dr. James Hansen, GISS/Code 940
Exceptional Scientific Achievement Medal	Dr. Hasso Niemann, Code 910
Outstanding Leadership Medal	Dr. Darryl Williams, Code 920
Exceptional Achievement Medal	Thomas W. Hamilton, Code 903, and William Campbell, Code 930
Exceptional Service Medal	Dr. Fritz Hasler, Code 910, and Kelly Pecnick, Code 903
Group Award	Global Change Master Directory (GCMD), Code 902

1997 Recipients of the Goddard Honor Awards:

Award of Merit	Dr. Louis S. Walter/Code 900
Exceptional Achievement Award	Prof. Benjamin Kedem/ U. of MD/Code 910 Dr. David A. Short/Code 910 Dr. Pawan K. Bhartia/Code 916 Mr. John F. Cavanaugh/Code 924
Group Achievement Award	The Earth Sciences Administration and Resources Management Office, Code 903 Infrared Spectral Imaging Radiometer (ISIR) Team, Code 912 The Forest Ecosystem Dynamics Project, Code 923 Regional Validation Center Development Team, Code 935

Dr. John Degnan, Head of Code 920.3, has been elevated to the grade of Senior Member in the Institute for Electrical and Electronics Engineers (IEEE), a distinction limited to about 8 % of the international membership.

The following employees received awards from the TOPEX/Poseidon Extended Mission NRA: Tony Busalacchi/970, David Ademec/970, Michele Reinecker/970, Chet Koblinsky/970, Doug Vandemark/970, George Hayne/970, Dave Hancock/970, Ben Chao/920, David Smith/970, and Dick Rapp/Ohio State.

Dr. Bill Lau (Code 910) presented a paper "Can ENSO be used as a surrogate for climate change" in the Distinguished Lecturer Series jointly organized by the University of Colorado Program for Atmosphere and Ocean Studies (PAO) and the NOAA Climate Dynamics Center (CDC) on January 15, 1997. The Distinguished Lectureship is chosen from a very select group of international scientists who have senior standing in the field of atmospheric and oceanic sciences. An award ceremony and a very nice certificate came after the seminar.

Dennis Chesters (Code 913), Paul Menzel, and Jim Purdom were given a special award for their roles in developing the capabilities of the GOES weather satellites at the AMS annual meeting in February 1997.

The TRMM Outstanding Performance Award was presented on February 11, 1997 to members of the TRMM Science Data and Information System (TSDIS) for their significant contributions to the TRMM project. Individual awards were received by Robert Mack (Code 902) and Ray Hinds (GSC, Code 902), and a team award was received by the Integration and Test Team, which consists of James Spero, Felix Wu, and Monica Starks.

Patricia Golden (Code 910) and Shannell Cardwell (Code 920) were selected as the recipients of the 1997 Annual Secretary Awards for Code 900.

Merritt Pharo (Code 910) received the Fireman of the Year award on December 7, 1997, from the Oak Grove Volunteer Fire Department.

(A little personal humor)

When a NASA geo-physicist (C. Voorhies, Code 921) replaced his 1981 Toyota Corolla with a 1994 GEO-Prizm, they gave him a license plate prefixed "DMH"—which abbreviates the rocket fuel DiMethylHydrazine.

We want to thank everyone who donated leave to me so that I could be on bedrest to assure that our twin girls would be healthy newborns. Without your kindness and generosity, we would have had much more to worry about.

Bobby and Tracy Baker

Did you know?

The TV show Newton's Apple, interested in tracking diseases from space satellites, contacted [Brian Montgomery](#) (Code 920) and posed a series of questions on remote sensing, GIS, and ecosystem modeling. They used this information in a show highlighting a team tracking malaria in South America. Brian was given credit as scientific consultant. The show will air this year.

The Goddard DAAC is providing technical support for the AMS/AGU/AAG electronic journal, "Earth Interactions" (<http://earthinteractions.org/>). DAAC personnel supported an exhibit of the "Earth Interactions" at the AGU fall meeting in December.

[Robert Langel](#) (formerly Code 920) sent the final version of his book *The Magnetic Field of the Earth's Lithosphere: The Satellite Perspective* to Cambridge Press, a final contribution in a long and productive career at Goddard. The book is expected to be available in time for next year's fall AGU meeting.

A recent report of detection of water ice at the permanently shaded south pole of the Moon has caused a media stir. [Paul Lowman](#) (Code 920) was interviewed by phone by National Public Radio and taped for CBS television news. [Jim Garvin](#) (Code 920) was quoted at some length in a *Washington Post* article.

[Paul Schopf](#) (Code 971) is leaving Goddard to take up a professorship at George Mason University.

Congratulations to Dr. Joanne Simpson

Goddard has named the agency's fastest supercomputer after Dr. Joanne Simpson, Chief Scientist for Meteorology. A dedication ceremony to name the Cray T3E supercomputer after Dr. Simpson was held on May 14, 1997. "It is a great honor to have such a remarkable supercomputer named after me," said Dr. Simpson.

An article featuring the GCMD was published in the final printed issue of the *Science Information Systems Newsletter*, Issue 40, entitled the "Global Change Master Directory Releases Version 5." The article was written by [Lola Olsen](#) (Code 902).

[Dr. Kevin Burke](#), University of Houston, is spending a sabbatical with Code 920 starting the first week in May. Kevin is very well known in the national and international geologic/geophysics community. He is generally considered to be the world expert on the geology of the Earth.

[Rosemarie Givens](#) (Code 903) is very proud of her children: [Diana Givens](#) received a Master's degree in Health Administration from Towson State University, where she is an instructor; [Dr. Timothy Givens](#) recently became the Associate Director of Pediatric Emergency Services at Kosair Hospital in Louisville, Kentucky; and [Richard Givens](#) was promoted to Head of Financial Services at Kaiser Permanente in Atlanta, Georgia.

Employees that have left Code 900:

Sheila Fennington/Code 903
Hong-Yee Chiu/Code 910
Joseph Johnston /Code 910
Joseph Famiglietti /Code 910
Robert Langel/Code 920
J. Andrew Marshall/Code 920
James Kalshoven/Code 920
Richard White/Code 930
Nikki Mayo/Code 930
Robert Field/Code 940
Helen Shirk/Code 970
Paul Schopf/Code 970

New Employees:

Darnell Tabb/Code 902
Connie Kroneman/Code 902
Jeff Privette/Code 920
David Pierce/Code 920
Tom Zagwodzki/Code 920
Sol Broder/Code 920
David Batchelor/Code 930
Jacqueline Haywood/Code 930
John Gerlach/Code 970
Paul Houser/Code 970



(Continued from Can You Trust Data, page 10)

round-robin calibrations, hands-on participation, development of radiometric artifacts, and joint validation field campaigns. In short, calibration activities suffuse the entire EOS endeavor.

As a result of the May 1996 vicarious calibration campaign at Railroad Valley/Lunar Lake, Nevada, several measurement and analysis areas were confidently identified as areas where the adoption of common, accepted procedures and approaches could reduce the overall scatter in the predicted top-of-the-atmosphere radiances. Examples of these areas include the determination of the reflectance of diffuse panels used in the calibration of the field radiometers and the use of different radiative transfer codes. "This is a place where NIST will help," said Butler. "There is a need for NIST to be involved in the formulation of protocols, the development of measurement

procedures, and possibly in providing NIST-calibrated diffuse panels for field use."

Similar campaigns are undertaken to help remote sensing instrument designers refine their designs. Aircraft underflight activities, managed at Goddard by Abel, provide a measure of what the instrument gain might be in a satellite sensor as it flies over a suitable ground target, by simultaneously observing the target with an aircraft. "The rationale is that if we can put an aircraft instrument above much of the atmosphere, essentially at the same height as the satellite for radiometric purposes, and looking along the same direction, then we can get a really simple measure of the radiance of the target, which we can compare with what the satellite sees—a direct measure of the gain of the satellite sensor." It's much more direct and much more accurate than any ground-based measurements, which use a lot of inferences and assumptions about

the atmospheric state, and surface states. "The problem is that it's much more expensive because of flight time and because you've got to plan weeks or months in advance," says Abel.

Such painstaking attention to detail is what allows all this multiorganization activity to result in state-of-the-art calibration capabilities that are now pushing the edge of the envelope in technology. The accuracies so obtained are greater than what is needed for the design and implementation of practical instruments. As a result, the "marriage" of existing and coming data sets will be a long and fruitful one, allowing Earth scientists to obtain an accurate and precise view of our planet's myriad interacting systems.



Dr. Mitchell K. Hobish

(Continued from Studying Magnetic Fields, page 13)

various coordinate systems were accounted for.

These problems were overcome and the resulting model provides a good representation of the data. Comparison with what is known about magnetospheric and ionospheric fields from other studies shows good agreement. At the same time, there is room for improvement. The ionospheric fields are known to vary with the solar cycle, geography, and other elements. These and other considerations are being taken into account in ongoing work.

There is, however, an interesting twist to the crustal field element. Another study with which Langel

was involved determined that one cannot always assume that the rocks in Earth's crust are magnetized in the same direction as Earth's core field. The team basically allowed the model itself to determine the direction of the crustal field. With that, the output showed that there is a strong component in the direction of the core field, but there is also a strong component in another direction. This may be an indicator that the usual assumption is incorrect in some regions of Earth.

All of this work simply reaffirms Langel's place at the cutting edge of geomagnetics, which is a somewhat uncomfortable place for him to be. Even though he has been nominated for and won awards ranging from the

NASA Exceptional Scientific Achievement Medal to becoming a Fellow of the American Geophysical Union, Lange's colleagues insist that he is a man of modesty and principle, never allowing his scientific conclusions or achievements to be taken out of context or applied in ways that are not realistic. Langel does science for the sake of learning—a refreshing and somewhat enviable position given the current climate of constant justification. Retirement from Goddard is just a change in the career path that will allow him to continue his pursuit of knowledge.



Kathy Pedelty